

Amendments to the Specification:

Please replace paragraphs [0006], [0013]-[0015], [0018]-[0023], and [0026]-[0048] with the following amended paragraphs:

[0006] Figure 1B is a diagram illustrating a pair of adjacent dice ~~dies~~ in the stack according to one embodiment of the invention.

[0013] Figure 6 is a flowchart illustrating a process to stack the dice ~~dies~~ according to one embodiment of the invention.

[0014] An embodiment of the present invention is a technique to stack dice ~~dies~~ in a die assembly. A plurality of dice ~~dies~~ are stacked on top of one another in a staggering configuration such that an upper die in a pair of adjacent dice ~~dies~~ face downward or upward and is displaced by a first distance with respect to a lower die in the pair. The adjacent dice ~~dies~~ are attached by an adhesive layer between the adjacent dice ~~dies~~.

[0015] In another embodiment, an upper die having upper first, second, third, and fourth edges is stacked on top of a lower die having lower first, second, third, and fourth edges such that the upper first edge is displaced from the lower first edge by a first distance. The upper first and third edges are opposite to each other. The lower first and third edges are opposite to each other. The upper die is attached to the lower die by a first adhesive layer deposited between the upper and lower dice ~~dies~~.

[0018] Figure 1A is a diagram illustrating a package assembly 100 in which one embodiment of the invention can be practiced. The package assembly includes a substrate 110, a plurality of dice ~~dies~~ 120₁ to 120_N, a plurality of bond pads 130₁ to 130_K, and a plurality of conductors 140₁ to 140_M.

[0019] The substrate 110 is any suitable substrate made of material such as silicon. The substrate 110 may also be a printed circuit board (PCB). The substrate 110 has a number of bond pads to provide interconnections to the dice ~~dies~~. The plurality of dice ~~dies~~ 120₁ to 120_N form a stack and include dice ~~dies~~ stacked on top of one another. Each die is an integrated circuit (IC) or a chip. The number of dice ~~dies~~ in the stack may be any suitable number, odd or

even, depending on the desired height. For example, the number of dice dies may be 4, 5, 6, 9 or 10.

[0020] Each of the dice dies has a number of bond pads 130_j 's ($j = 1, \dots, K$) to provide contact for interconnections. The number of bond pads on each die may vary. When the bond pads are not suitably placed, a redistribution layer (not shown) may be formed to redistribute the interconnection pattern. The conductors 140_k 's ($i = 1, \dots, M$) connect the bond pads from the dice dies to the bond pads on the substrate. The conductors 140_k 's may be wires or conducting material or paths that form electrical connections between the bond pads.

[0021] The dice dies in the stack are arranged in a staggering pattern. The staggering configuration may be stair-case in one dimension or two dimensions, or alternate. The staggering configuration allows the adjacent dice dies to be placed off-center, i.e., adjacent dice dies are displaced with respect to each other by a distance. The distance is selected so that the conductors connecting the bond pads on the dice dies to the bond pads on the substrate 110 are separated by a conductor distance to avoid touching or crossing each other.

[0022] By offsetting the dice dies with respect to one another in the stack, no spacers are needed. The dice dies in essence act like the spacers themselves. The advantages of offsetting the dice dies in the stack includes more dice dies for a given height, reduced assembly time, and increased reliability and yield due to less interfacing problems.

[0023] Figure 1B is a diagram illustrating a pair 120_k of adjacent dice dies in the stack according to one embodiment of the invention. The pair 120_k includes an upper die 122 and a lower die 125 and an adhesive layer 127. The stack 120 includes a number of layers having a number of pairs 120_k stacked on top of one another. The number of layers may be odd or even. The upper and lower dice dies 122 and 125 may have same or substantially similar sizes and/or geometries.

[0026] The upper die 122 is stacked on top of the lower die 125 such that the upper first edge is displaced from the lower first edge by a first distance d_1 . The upper die 122 may also be displaced by any angle with respect to the lower die 125. The stacking may also be extended to the other dimension such that the upper second edge is displaced from the lower second edge by a second distance d_2 . The adhesive layer is deposited between the upper and lower dice dies 122 and

125 to attach these two dice dies together. In one embodiment, the adhesive layer is made of an adhesive material such as epoxy and can be filled with non-conductive or conductive particles.

[0027] The upper die 122 and the lower die 125 may be stacked as shown in Fig. 1B, i.e., the bottom surface of the upper die 122 is attached to the top surface of the lower die 125. In another embodiment, the top of the upper die 122 and the top of the lower die 125 may face to each other. In other words, the upper die 122 is turned upside down such that its upper surface is attached to the upper surface of the lower die 125. The two dice dies can be stacked in any configuration, as long as there is an unobstructed area for the bond pads. This unobstructed area may face upward or downward depending on whether the corresponding die faces upward or downward, respectively.

[0028] For interconnection, the conductors are connected or attached to the bond pads of the dice dies. For example, upper conductor 142 is attached to the upper bond pad of the upper die 122 and lower conductor 144 is attached to the lower bond pad of the lower die 125. Since the dice dies are offset to each other by a distance, the upper conductor 142 and the lower conductor 144 are separated by a conductor distance. When the bond pads face downward, the resulting conductor interconnections may provide space efficiency and/or design flexibility for the layout on the substrate surface.

[0029] The stack of dice dies 120 includes any number of layers including pairs like the pair 120_k stacked on top of one another. Depending on how these pairs are stacked on one another, there are a number of staggering configurations of the entire stack. Examples of these configurations include a stair-case configuration in one dimension, a stair-case configuration in both dimensions, an alternate staggering configuration in one dimension, and an alternate staggering configuration in both dimensions.

[0030] Figure 2A is a diagram illustrating a cross-sectional view of a stair-case configuration according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0031] The four dice dies 120₁ to 120₄ are arranged in a stair-case configuration. In this configuration, the dice dies are offset by a distance in a stair-case pattern. Between adjacent dice dies, there is an adhesive layer 127_i's ($i = 1, \dots, 4$) to attach the adjacent dice dies together. The

thickness of the adhesive layer may be 0.001". Since the thickness of the adhesive layer 127_i's is much less than that of a conventional spacer, more dice dies can be stacked together for the same height. The bottom die 120₁ is attached to the substrate by the same adhesive layer 127₁.

[0032] The conductors 140₁ to 140₄ are representative of conductors connecting the die bond pads to the substrate bond pads. Since the dice dies are offset by a distance, the conductors 140₁ to 140₄ are also offset by a conductor distance sufficiently large to separate the conductors. The conductors 140₄ and 140₂ are shown beneath the corresponding die 120₄ and 120₂ because these two dice dies face downward to the respective lower dice dies. The dice dies are stacked in pairs by having the two dice dies in each pair face to each other, i.e., their upper surfaces are attached by the adhesive layer. As shown in Fig. 2A, dice dies 2 and 4 120₂ and 120₄ are turned upside down so that the exposed bond path faces downward.

[0033] Figure 2B is a diagram illustrating a top view of a stair-case configuration according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0034] The dice dies are offset by a distance d_1 . The distance d_1 may be the same or different for each pair of adjacent dice dies. In addition, the distance d_1 may be constant or variable depending on the relative orientation of the two adjacent dice dies. The conductors 140_j's connect the bond pads of the dice dies on the stair-case side of the stack.

[0035] Figure 3 is a diagram illustrating a top view of a stair-case configuration in both dimensions according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0036] In this configuration, the dice dies are offset in both directions or dimensions by distances d_1 and d_2 . The conductors connect the bond pads on both stair-case sides of each die to the bond pads of the substrate. As in Figure 2B, the dice dies 120₂ and 120₄ face toward their respective lower dice dies, i.e., die 120₁ and 120₃, respectively. The conductors 140₂ and 140₄ are connected to the bond pads on the dice dies 120₂ and 120₄ facing downward.

[0037] Figure 4A is a diagram illustrating a cross-sectional view of an alternate staggering configuration according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0038] In this configuration, the dice dies 120₁ to 120₄ are arranged in a zigzag or alternate pattern. Dice Dies form in pairs of adjacent dice dies. The dice dies may face together in the same direction or in opposite directions. In each pair, the upper die is offset from the lower die by a distance. The pairs are then stacked onto one another in alignment, resulting in an alternate staggering pattern. For example, dice dies 120₁ and 120₃ are aligned and dice dies 120₂ and 102₄ are aligned.

[0039] In another embodiment, in each pair, the dice dies may face toward each other, i.e., the upper die is turned upside down as discussed above.

[0040] The conductors 140_j's are connecting the bond pads in both sides of the dice dies. On one side, the conductors 140_j's connect the bond pads of the lower dice dies in the pairs to one side of the substrate. On the other side, the conductors 140_j's connect the bond pads of the upper dice dies in the pairs to the other side of the substrate.

[0041] Figure 4B is a diagram illustrating a top view of an alternate staggering configuration according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0042] In this top view, only the upper pair is visible showing the dice dies 120₃ and 120₄. The lower pair including the dice dies 120₁ and 120₂ are hidden as viewed from the top. The conductors are shown to connect the bond pads of the dice dies to the bond pads of the substrate on both opposite sides of the stack of dice dies.

[0043] Figure 5 is a diagram illustrating a top view of an alternate staggering configuration in both dimensions according to one embodiment of the invention. For illustrative purposes, four dice dies are shown.

[0044] In this configuration, the dice dies are arranged in the alternate staggering pattern in both directions or dimensions. As seen from the top, only the upper pair is visible showing the dice dies 120₃ and 120₄. The lower pair including the dice dies 120₁ and 120₂ are hidden as viewed from the top. The conductors are shown to connect the bond pads of the dice dies to the bond pads of the substrate on all four sides of the stack of dice dies.

[0045] Figure 6 is a flowchart illustrating a process 600 to stack the dice dies according to one embodiment of the invention.

[0046] Upon START, the process 600 determines if there are bond pads on the die at the exposed edges for interconnections (Block 610). If not, the process 600 deposits redistribution layer to re-arrange the bond pads to suitable locations (Block 620) and then goes to Block 630. Otherwise, the process 600 deposits an adhesive layer on the lower die to attach the lower die to the upper die (Block 630). The adhesive layer is deposited to cover sufficient surface areas between the two dice dies. Next, the process 600 stacks an upper die on top of a lower die such that the upper first edge is displaced from the lower first edge by a distance (Block 640). The upper and lower dice dies may have the geometry as shown in Figure 1B. The upper die may face upward or downward with respect to the lower die.

[0047] Then, the process 600 attaches the upper and lower conductors to the upper and lower bond pads of the upper and lower dice dies, respectively, such that the conductors are separated by a conductor distance (Block 650).

[0048] Next, the process 600 attaches the bottom die in the stack to the substrate by an adhesive layer (Block 660). Then, the process 600 stacks dice dies on top of one another in one of a stair-case and alternate staggering configurations (Block 660) and is then terminated. The staggering or displacement of the dice dies may be parallel to a die edge or approximately diagonal to a die edge.